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|---|---|
| L4 and neuro$10 and oscillat$6 | 22 |

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| L5 | L4 and neuro$10 and oscillat$6 | 22 | L5 |
| L4 | 706/26.ccls. | 202 | L4 |
| *DB=PGPB; PLUR=NO; OP=OR* | | | |
| L3 | 20020099676 | 1 | L3 |
| *DB=USPT; PLUR=NO; OP=OR* | | | |
| L2 | 6,327,583.pn. | 1 | L2 |
| L1 | 6,076,082.pn. | 1 | L1 |

END OF SEARCH HISTORY

# Hit List

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**Search Results** - Record(s) 1 through 22 of 22 returned.

☐ 1. Document ID: US 20030004907 A1

L5: Entry 1 of 22 File: PGPB Jan 2, 2003

PGPUB-DOCUMENT-NUMBER: 20030004907
PGPUB-FILING-TYPE: new
DOCUMENT-IDENTIFIER: US 20030004907 A1

TITLE: Pulse signal circuit, parallel processing circuit, pattern recognition system, and image input system

PUBLICATION-DATE: January 2, 2003

INVENTOR-INFORMATION:

| NAME | CITY | STATE | COUNTRY | RULE-47 |
|---|---|---|---|---|
| Matsugu, Masakazu | Chiba | | JP | |

US-CL-CURRENT: 706/26

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw. De

☐ 2. Document ID: US 20020091655 A1

L5: Entry 2 of 22 File: PGPB Jul 11, 2002

PGPUB-DOCUMENT-NUMBER: 20020091655
PGPUB-FILING-TYPE: new
DOCUMENT-IDENTIFIER: US 20020091655 A1

TITLE: System, method, and computer program product for representing object relationships in a multidimensional space

PUBLICATION-DATE: July 11, 2002

INVENTOR-INFORMATION:

| NAME | CITY | STATE | COUNTRY | RULE-47 |
|---|---|---|---|---|
| Agrafiotis, Dimitris K. | Downington | PA | US | |
| Rassokhin, Dmitrii N. | Exton | PA | US | |
| Lobanov, Victor S. | North Brunswick | NJ | US | |
| Salemme, F. Raymond | Yardley | PA | US | |

US-CL-CURRENT: 706/26; 706/15

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw D

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☐ 3. Document ID: US 6456992 B1

L5: Entry 3 of 22 File: USPT Sep 24, 2002

US-PAT-NO: 6456992
DOCUMENT-IDENTIFIER: US 6456992 B1

TITLE: Semiconductor arithmetic circuit

DATE-ISSUED: September 24, 2002

INVENTOR-INFORMATION:

| NAME | CITY | STATE | ZIP CODE | COUNTRY |
|---|---|---|---|---|
| Shibata; Tadashi | Miyagi-ken 982 | | | JP |
| Ohmi; Tadahiro | Miyagi-ken 980 | | | JP |
| Morimoto; Tatsuo | Miyagi-ken | | | JP |
| Kaiwara; Ryu | Miyagi-ken | | | JP |

US-CL-CURRENT: 706/33; 706/26, 706/34, 706/35, 706/42

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw D

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☐ 4. Document ID: US 6397201 B1

L5: Entry 4 of 22 File: USPT May 28, 2002

US-PAT-NO: 6397201
DOCUMENT-IDENTIFIER: US 6397201 B1

TITLE: E-cell (equivalent cell) and the basic circuit modules of e-circuits: e-cell pair totem, the basic memory circuit and association extension

DATE-ISSUED: May 28, 2002

INVENTOR-INFORMATION:

| NAME | CITY | STATE | ZIP CODE | COUNTRY |
|---|---|---|---|---|
| Arathorn; David W. | Oakland | CA | 94618 | |

US-CL-CURRENT: 706/33; 706/26, 706/40, 706/42

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw D

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☐ 5. Document ID: US 6363369 B1

L5: Entry 5 of 22 File: USPT Mar 26, 2002

US-PAT-NO: 6363369
DOCUMENT-IDENTIFIER: US 6363369 B1

TITLE: Dynamic synapse for signal processing in neural networks

DATE-ISSUED: March 26, 2002

INVENTOR-INFORMATION:

| NAME | CITY | STATE | ZIP CODE | COUNTRY |
|---|---|---|---|---|
| Liaw; Jim-Shih | Los Angeles | CA | | |
| Berger; Theodore W. | Los Angeles | CA | | |

US-CL-CURRENT: 706/15; 706/16, 706/26

| Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De |
|---|---|---|---|---|---|---|---|---|---|---|---|---|

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☐ 6. Document ID: US 6243490 B1

L5: Entry 6 of 22 File: USPT Jun 5, 2001

US-PAT-NO: 6243490
DOCUMENT-IDENTIFIER: US 6243490 B1
**** See image for Certificate of Correction ****

TITLE: Data processing using neural networks having conversion tables in an intermediate layer

DATE-ISSUED: June 5, 2001

INVENTOR-INFORMATION:

| NAME | CITY | STATE | ZIP CODE | COUNTRY |
|---|---|---|---|---|
| Mita; Yoshinobu | Kawasaki | | | JP |

US-CL-CURRENT: 382/158; 706/26

| Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De |
|---|---|---|---|---|---|---|---|---|---|---|---|---|

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☐ 7. Document ID: US 6169981 B1

L5: Entry 7 of 22 File: USPT Jan 2, 2001

US-PAT-NO: 6169981
DOCUMENT-IDENTIFIER: US 6169981 B1

TITLE: 3-brain architecture for an intelligent decision and control system

DATE-ISSUED: January 2, 2001

INVENTOR-INFORMATION:

| NAME | CITY | STATE | ZIP CODE | COUNTRY |
|---|---|---|---|---|

| | | | |
|---|---|---|---|
| Werbos; Paul J. | College Park | MD | 20740-2403 |

US-CL-CURRENT: 706/23; 706/15, 706/16, 706/26, 706/27

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

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☐ 8. Document ID: US 6134537 A

L5: Entry 8 of 22 File: USPT Oct 17, 2000

US-PAT-NO: 6134537
DOCUMENT-IDENTIFIER: US 6134537 A

TITLE: Visualization and self organization of multidimensional data through equalized orthogonal mapping

DATE-ISSUED: October 17, 2000

INVENTOR-INFORMATION:

| NAME | CITY | STATE | ZIP CODE | COUNTRY |
|---|---|---|---|---|
| Pao; Yoh-Han | Cleveland Heights | OH | | |
| Meng; Zhuo | Cleveland | OH | | |

US-CL-CURRENT: 706/16; 706/18, 706/25, 706/26

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

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☐ 9. Document ID: US 6016154 A

L5: Entry 9 of 22 File: USPT Jan 18, 2000

US-PAT-NO: 6016154
DOCUMENT-IDENTIFIER: US 6016154 A

TITLE: Image forming apparatus

DATE-ISSUED: January 18, 2000

INVENTOR-INFORMATION:

| NAME | CITY | STATE | ZIP CODE | COUNTRY |
|---|---|---|---|---|
| Moroo; Jun | Kawasaki | | | JP |
| Mikami; Tomohisa | Kawasaki | | | JP |
| Mori; Masahiro | Kawasaki | | | JP |
| Chiba; Hirotaka | Kawasaki | | | JP |
| Nagata; Shigemi | Kawasaki | | | JP |
| Nakamura; Shigeyoshi | Kawasaki | | | JP |
| Konaka; Toshio | Kawasaki | | | JP |
| Sato; Kazuhiko | Kawasaki | | | JP |

US-CL-CURRENT: 345/442; 345/428, 345/581, 345/611, 345/615, 345/690, 706/22, 706/26, 706/31

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

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☐ 10. Document ID: US 5956703 A

L5: Entry 10 of 22 File: USPT Sep 21, 1999

US-PAT-NO: 5956703
DOCUMENT-IDENTIFIER: US 5956703 A

TITLE: Configurable neural network integrated circuit

DATE-ISSUED: September 21, 1999

INVENTOR-INFORMATION:

| NAME | CITY | STATE | ZIP CODE | COUNTRY |
|---|---|---|---|---|
| Turner; Douglas D. | Kokomo | IN | | |
| Breuer; Gabriela | Santa Barbara | CA | | |

US-CL-CURRENT: 706/27; 706/26, 706/31

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

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☐ 11. Document ID: US 5864693 A

L5: Entry 11 of 22 File: USPT Jan 26, 1999

US-PAT-NO: 5864693
DOCUMENT-IDENTIFIER: US 5864693 A

TITLE: Movement control method and chaotic information processing unit using chaotic neural network, and group movement control method

DATE-ISSUED: January 26, 1999

INVENTOR-INFORMATION:

| NAME | CITY | STATE | ZIP CODE | COUNTRY |
|---|---|---|---|---|
| Sawamura; Tsuguo | Chigasaki | | | JP |

US-CL-CURRENT: 700/246; 706/23, 706/26, 708/522

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

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☐ 12. Document ID: US 5535303 A

L5: Entry 12 of 22 File: USPT Jul 9, 1996

US-PAT-NO: 5535303

DOCUMENT-IDENTIFIER: US 5535303 A

TITLE: "Barometer" neuron for a neural network

DATE-ISSUED: July 9, 1996

INVENTOR-INFORMATION:

| NAME | CITY | STATE | ZIP CODE | COUNTRY |
|---|---|---|---|---|
| Ekchian; Leon K. | Northridge | CA | | |
| Johnson; David D. | Simi Valley | CA | | |
| Smith; William F. | Los Angeles | CA | | |

US-CL-CURRENT: 706/26; 706/15, 706/24, 706/25

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

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☐ 13. Document ID: US 5517597 A

L5: Entry 13 of 22 File: USPT May 14, 1996

US-PAT-NO: 5517597
DOCUMENT-IDENTIFIER: US 5517597 A

TITLE: Convolutional expert neural system (ConExNS)

DATE-ISSUED: May 14, 1996

INVENTOR-INFORMATION:

| NAME | CITY | STATE | ZIP CODE | COUNTRY |
|---|---|---|---|---|
| Aparicio, IV; Manuel | Arlington | TX | | |
| Otto; Samuel E. | Grapevine | TX | | |

US-CL-CURRENT: 706/26; 706/15, 706/25

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

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☐ 14. Document ID: US 5446828 A

L5: Entry 14 of 22 File: USPT Aug 29, 1995

US-PAT-NO: 5446828
DOCUMENT-IDENTIFIER: US 5446828 A

TITLE: Nonlinear neural network oscillator

DATE-ISSUED: August 29, 1995

INVENTOR-INFORMATION:

| NAME | CITY | STATE | ZIP CODE | COUNTRY |
|---|---|---|---|---|
| Woodall; Roger L. | Jewett City | CT | | |

US-CL-CURRENT: 706/25; 706/16, 706/26

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

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☐ 15. Document ID: US 5357597 A

L5: Entry 15 of 22 File: USPT Oct 18, 1994

US-PAT-NO: 5357597
DOCUMENT-IDENTIFIER: US 5357597 A

TITLE: Convolutional expert neural system (ConExNS)

DATE-ISSUED: October 18, 1994

INVENTOR-INFORMATION:

| NAME | CITY | STATE | ZIP CODE | COUNTRY |
|---|---|---|---|---|
| Aparicio, IV; Manuel | Arlington | TX | | |
| Otto; Samuel E. | Grapevine | TX | | |

US-CL-CURRENT: 706/25; 706/26

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

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☐ 16. Document ID: US 5355435 A

L5: Entry 16 of 22 File: USPT Oct 11, 1994

US-PAT-NO: 5355435
DOCUMENT-IDENTIFIER: US 5355435 A

TITLE: Asynchronous temporal neural processing element

DATE-ISSUED: October 11, 1994

INVENTOR-INFORMATION:

| NAME | CITY | STATE | ZIP CODE | COUNTRY |
|---|---|---|---|---|
| DeYong; Mark R. | Las Cruces | NM | | |
| Findley; Randall L. | Austin | TX | | |
| Eskridge; Thomas C. | Las Cruces | NM | | |
| Fields; Christopher A. | Rockville | MD | | |

US-CL-CURRENT: 706/26

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

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☐ 17. Document ID: US 5297232 A

L5: Entry 17 of 22 File: USPT Mar 22, 1994

US-PAT-NO: 5297232
DOCUMENT-IDENTIFIER: US 5297232 A

TITLE: Wireless neural network and a wireless neural processing element

DATE-ISSUED: March 22, 1994

INVENTOR-INFORMATION:

| NAME | CITY | STATE | ZIP CODE | COUNTRY |
|---|---|---|---|---|
| Murphy; John H. | Churchill Boro. | PA | | |

US-CL-CURRENT: 706/26

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Drawu De

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☐ 18. Document ID: US 5222193 A

L5: Entry 18 of 22 File: USPT Jun 22, 1993

US-PAT-NO: 5222193
DOCUMENT-IDENTIFIER: US 5222193 A

TITLE: Training system for neural networks and the like

DATE-ISSUED: June 22, 1993

INVENTOR-INFORMATION:

| NAME | CITY | STATE | ZIP CODE | COUNTRY |
|---|---|---|---|---|
| Brooks; William O. | Aloha | OR | | |
| Cossitt; Alan J. | Portland | OR | | |
| Helm; Richard K. | Aloha | OR | | |
| Johnson; Louis J. | Beaverton | OR | | |
| McNamee; Raymond E. | Boring | OR | | |

US-CL-CURRENT: 706/25; 706/15, 706/26

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Drawu De

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☐ 19. Document ID: US 5214745 A

L5: Entry 19 of 22 File: USPT May 25, 1993

US-PAT-NO: 5214745
DOCUMENT-IDENTIFIER: US 5214745 A

TITLE: Artificial neural device utilizing phase orientation in the complex number domain to encode and decode stimulus response patterns

DATE-ISSUED: May 25, 1993

INVENTOR-INFORMATION:

| NAME | CITY | STATE | ZIP CODE | COUNTRY |
|---|---|---|---|---|
| Sutherland; John G. | Hamilton, Ontario | | | CA |

US-CL-CURRENT: 706/17; 706/25, 706/26

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

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☐ 20. Document ID: US 5072130 A

L5: Entry 20 of 22 File: USPT Dec 10, 1991

US-PAT-NO: 5072130
DOCUMENT-IDENTIFIER: US 5072130 A

TITLE: Associative network and signal handling element therefor for processing data

DATE-ISSUED: December 10, 1991

INVENTOR-INFORMATION:

| NAME | CITY | STATE | ZIP CODE | COUNTRY |
|---|---|---|---|---|
| Dobson; Vernon G. | Oxford, OX2 OHH | | | GB2 |

US-CL-CURRENT: 706/26; 326/35, 706/18, 706/22, 706/34, 708/801

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

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☐ 21. Document ID: US 4926064 A

L5: Entry 21 of 22 File: USPT May 15, 1990

US-PAT-NO: 4926064
DOCUMENT-IDENTIFIER: US 4926064 A

TITLE: Sleep refreshed memory for neural network

DATE-ISSUED: May 15, 1990

INVENTOR-INFORMATION:

| NAME | CITY | STATE | ZIP CODE | COUNTRY |
|---|---|---|---|---|
| Tapang; Carlos C. | Portland | OR | | |

US-CL-CURRENT: 706/26; 326/35, 706/25, 706/30, 706/38, 708/801

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

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☐ 22. Document ID: US 3237025 A

L5: Entry 22 of 22 File: USOC Feb 22, 1966

US-PAT-NO: 3237025
DOCUMENT-IDENTIFIER: US 3237025 A

TITLE: Comparator circuit

DATE-ISSUED: February 22, 1966

INVENTOR-NAME: CLAPPER GENUNG L

US-CL-CURRENT: 326/35; 327/357, 340/146.2, 706/26

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

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| L4 and neuro$10 and oscillat$6 | 22 |

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Previous Page  Next Page  Go to Doc#

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| L6 | L4 and neuro$10 and nonlinear adj oscillat$6 | 1 | L6 |
| L5 | L4 and neuro$10 and oscillat$6 | 22 | L5 |
| L4 | 706/26.ccls. | 202 | L4 |
| | *DB=PGPB; PLUR=NO; OP=OR* | | |
| L3 | 20020099676 | 1 | L3 |
| | *DB=USPT; PLUR=NO; OP=OR* | | |
| L2 | 6,327,583.pn. | 1 | L2 |
| L1 | 6,076,082.pn. | 1 | L1 |

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# Hit List

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**Search Results -** Record(s) 1 through 1 of 1 returned.

☐ 1. Document ID: US 5446828 A

L6: Entry 1 of 1 File: USPT Aug 29, 1995

US-PAT-NO: 5446828
DOCUMENT-IDENTIFIER: US 5446828 A

TITLE: Nonlinear neural network oscillator

DATE-ISSUED: August 29, 1995

INVENTOR-INFORMATION:

| NAME | CITY | STATE | ZIP CODE | COUNTRY |
|---|---|---|---|---|
| Woodall; Roger L. | Jewett City | CT | | |

US-CL-CURRENT: 706/25; 706/16, 706/26

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

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*Linsay, P.S.; DeLiang L. Wang;*
Neural Networks, IEEE Transactions on , Volume: 9 Issue: 3 , May 1998
Page(s): 523 -532

[Abstract] [PDF Full-Text (276 KB)] **IEEE JNL**

---

2 **The dynamics of coupled nonlinear oscillators: from relaxation osci to neurons**
*Linsay, P.S.; Brailove, A.A.; Gaudiano, P.; Przybyszewski, A.; Wilson, C.;*
Circuits and Systems, 1996. ISCAS '96., 'Connecting the World'., 1996 IEEE International Symposium on , Volume: 3 , 12-15 May 1996
Page(s): 138 -141 vol.3

[Abstract] [PDF Full-Text (352 KB)] **IEEE CNF**

---

3 **Secure communications and unstable periodic orbits of strange att**
*Abarbanel, H.D.I.; Linsay, P.S.;*
Circuits and Systems II: Analog and Digital Signal Processing, IEEE Transacti
Volume: 40 Issue: 10 , Oct. 1993
Page(s): 643 -645

[Abstract] [PDF Full-Text (296 KB)] **IEEE JNL**

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**Adaptive Synchronization of Neural and Physical Oscillators (1992)** (Make Corrections) (2 citations)
Kenji Doya, Shuji Yoshizawa
Advances in Neural Information Processing Systems

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**Abstract:** Animal locomotion patterns are controlled by recurrent neural networks called central pattern generators (CPGs). Although a CPG can oscillate autonomously, its rhythm and phase must be well coordinated with the state of the physical system using sensory inputs. In this paper we propose a learning algorithm for synchronizing neural and physical oscillators with specific phase relationships. Sensory input connections are modified by the correlation between cellular activities and input signals.... (Update)

**Context of citations to this paper: More**

...One drawback of these systems is that they are very di#cult to tune. **In spite of theoretical work on oscillators (e.g. 4] and learning [3], there is a lack of practical knowledge of how the oscillators work and how to design systems using them.** This paper presents a method...

...4. The zero legged robot by Doya and Yoshizawa (1992) We applied the learning rule to the control of a zerolegged robot (Fig. **4) [14].** The robot consists of a wheel and a weight which moves along a track fixed radially in the wheel. The periodic control signal to the weight...

**Cited by: More**
A Learning Model for a Neural Oscillator to Generate a Locomotor.. - Nishii (1997) (Correct)
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    title = "Adaptive Synchronization of Neural and Physical Oscillators",
    booktitle = "Advances in Neural Information Processing Systems",
    volume = "4",
    publisher = "Morgan Kaufmann Publishers, Inc.",
    editor = "John E. Moody and Steve J. Hanson and Richard P. Lippmann",
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309 Adaptive Signal Processing (context) - Widrow, Stearns - 1985
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42 Learning to control an unstable system with forward modeling (context) - Jordan, Jacobs - 1990
18 Adaptive neural oscillator using continuous-time back-propag.. (context) - Doya, Yoshizawa - 1989
8 An Introduction to Neural and Electronic Networks (context) - Zornetzer, eds - 1986 **Book Details from Amazon or Barnes & Noble**
4 Two coupled neural oscillators as a model of the circadian p.. (context) - Kawato, Suzuki - 1980
2 The neural network underlying locomotion in Lamprey---Synapt.. (context) - Grillner, Matsushima - 1991
1 Feedback and Motor Control in Invertebrates and Vertebrates (context) - Barnes, Gladden - 1985
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**Documents on the same site (http://www.erato.atr.co.jp/~doya/pubs98.html): More**

Efficient Nonlinear Control with Actor-Tutor Architecture - Kenji Doya (1997) (Correct)
Reinforcement Learning with Multiple Representations in The.. - Hiroyuki Nakahara (Correct)
Bifurcations In The Learning Of Recurrent Neural Networks - Kenji Doya (1992) (Correct)

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**Doya, K. and Yoshizawa, S., "*Adaptive neural oscillator using continuous-time back-propagation learning*", Neural Networks, Vol. 2, pp.375-385 (1989)**



This paper is cited in the following contexts:

Simple Learning Algorithm for Recurrent Networks - To Realize Short-Term (Correct)

....Conventional Learning Algorithm Two typical learning algorithms for the recurrent neural network are proposed One is BPTT (Back Propagation Through Time) 1] etc. **for** discrete time, 2] etc. **for** continuous time) and the other is RTRL (Real Time Recurrent Learning) 3] etc. **for discrete time, [4] etc.** for continuous time) In BPTT, it is necessary to make the error propagate to the past. **This** means that the past states of the neural network have to be stored. **If** the propagation is truncatedat T time step, that is called truncated BPTT(T) the neural network cannot memorize the signals ....

Doya, K. and Yoshizawa, S., "*Adaptive neural oscillator using continuous-time back-propagation learning*", Neural Networks, Vol. 2, pp.375-385 (1989)

Learning Precise Timing with LSTM Recurrent Networks - Gers, Schmidhuber, Schraudolph (Correct)

....production of continual spike trains, where the interval between spikes must re ect the magnitude of an input signal that may change after every spike. **GTS is a special case of periodic function generation (PFG, see below) In contrast to previously studied PFG tasks (Williams Zipser, 1989; Doya Yoshizawa, 1989; Tsung Cottrell, 1995) GTS is highly nonlinear and involves long time lags between signi cant output changes, which cannot be learned by conventional RNNs.** Previous work also did not focus on stability issues. **Here**, by contrast, we demand that the generation be stable for 1000 successive ....

.... **are learnable by fully connected teacherforced RNNs whose units are all output units with teacher de ned activations (Williams Zipser, 1989) An alternative approach trains an RNN to predict the next input; after training outputs are fed back directly to the input so as to generate the waveform (Doya Yoshizawa, 1989; Tsung Cottrell, 1995; Weiss, 1999; Townley, Ilchmann, Weiss, McClements, Ruiz, Owens, PraetzelWolters, 1999) Here we focus on more dicult, highly nonlinear, triangular and rectangular waveforms, the latter featuring long time lags between signi cant output changes.** Again, traditional RNNs ....

Doya, K., &Yoshizawa, S. (1989). *Adaptive neural oscillator using continuous-time backpropagation learning.*

Learning Oscillations Using Adaptive Control - Weiss (1997) (2 citations) (Correct)

.... **Using Adaptive Control Martin Georg Wei Graduiertenkolleg Technomathematik Universitat Kaiserslautern Erwin Schrodinger Stra e 67663 Kaiserslautern, Germany September 8, 1997 Abstract We study a model for learning periodic signals in recurrent neural networks proposed by Doya and Yoshizawa [7] that can be considered as a model for temporal pattern memory in animal motoric systems.** A network receives an external oscillatory input and adjusts its weights so that this signal can be reproduced

approximately as the network output after some time. **We** use tools from adaptive control theory to ....

....to the theory of linear time varying systems where this condition is generically tue (under assumptions which are also needed in the time invariant case) However we cannot show that the linearized system related to the nonlinear neural network fulfils these generic assumptions. **1 Introduction In [7] the following model for learning of motions was proposed: Trajectories of motion are assumed to be stored in some parts of the motor nervous system.** Whenever we try to memorize a new motion, e.g. riding a bicycle or swimming, we achieve our goal by conscious repetition in a way of supervised ....

[Article contains additional citation context not shown here]

K. Doya and S. Yoshizawa. *Adaptive neural oscillator using continuous time back-propagation.* Neural Networks, 2:375--385, 1989.

---

Gradient-Based Learning Algorithms for Recurrent Networks.. - Williams, Zipser (1995) (47 citations) (Correct)

.... **This algorithm has been independently derived in various forms by Robinson and Fallside (1987) Kuhn (1987) Bachrach (1988, chapter , this volume] Mozer (1989, chapter , this volume] and Williams and Zipser (1989a) and continuous time versions have been proposed by Gherrity (1989) Doya and Yoshizawa (1989), and Sato (1990a; 1990b) 5.**1 The Algorithm For each k 2 U , i 2 U , j 2 U [ I, and t 0 t t 1 , we define p k ij (t) y k (t) w ij : 31) This quantity measures the sensitivity of the value of the output of the k th unit at time t to a small increase in the value of w ij , taking into ....

....an approximation algorithm would provide an interesting blend of aspects of both truncated BPTT and subgrouped RTRL. **9 Teacher Forcing An interesting strategy that has appeared implicitly or explicitly in the work of a number of investigators studying supervised learning tasks for recurrent nets (Doya Yoshizawa, 1989; Jordan, 1986; Narendra Parthasarathy, 1990; Pineda, 1988; Rohwer Renals, 1989; Williams Zipser, 1989a; 1989b) is to replace, during training, the actual output y k (t) of a unit by the teacher signal d k (t) in subsequent computation of the behavior of the network, whenever such a target** ....

Doya, K. & Yoshizawa, S. (1989). *Adaptive neural oscillator using continuous-time back-propagation learning.* Neural Networks, 2, 375-385.

---

Memory and Learning of Sequential Patterns by Nonmonotone.. - Masahiko Morita (1996) (2 citations) (Correct)

....association model. **One might think that this is due to the improper weight matrix and that synchronization will not be necessary if the pattern sequence is stored using a proper learning algorithm such as the recurrent back propagation (BP) algorithm (e.g. Pineda, 1987; Pearlmutter, 1989; Doya Yoshizawa, 1989).** Actually however, as long as the network dynamics is time continuous, learning is not achieved unless the size of the network is small enough and very limited patterns are learned. **The** reason for this is that the BP learning only attempts to minimize the difference (mean square errors) between ....

Doya, K., & Yoshizawa, S. (1989). *Adaptive neural oscillator using continuous-time backpropagation learning.* Neural Networks, 2, 375--385.

---

Gradient-Based Learning Algorithms for Recurrent.. - Williams, Zipser (1990) (16 citations) (Correct)

.... **we have called real time recurrent learning (RTRL) This algorithm has been independently derived in various forms by Robinson and Fallside (1987) Kuhn (1987) Bachrach (1988) Mozer (1988) and Williams and Zipser (1989a) and continuous time versions have been proposed by Gherrity (1989) and by Doya and Yoshizawa (1989).** 5.1 The Algorithm For each k 2 U , i 2 U , j 2 U [ I, and t 0 t t 1 , we define p k ij (t) y k (t) w ij : 28) This quantity measures the sensitivity of the value of the output of the k th unit at time t to a small increase in the value of w ij , taking into account the effect of ....

....an approximation algorithm would provide an interesting blend of aspects of both truncated BPTT and subgrouped RTRL. **9 Teacher Forcing An interesting strategy that has appeared implicitly or explicitly in the work of a number of investigators studying supervised learning tasks for recurrent nets (Doya Yoshizawa, 1989; Jordan, 1986; Narendra Parthasarathy, 1988; Pineda, 1988; Rohwer Renals, 1989; Williams Zipser, 1989a; 1989b) is to replace, during training, the actual output y k (t) of a unit by the**

**teacher signal d k (t) in subsequent computation of the behavior of the network, whenever such a target** ....

Doya, K. &Yoshizawa, S. (1989). *Adaptive neural oscillator using continuous-time back-propagation learning*. Neural Networks, 2, 375-385.

---

Existence and Learning of Oscillations in Recurrent .. - Townley, Ilchmann, .. (1999) (2 citations) (Correct)

....RNN can generate a stable limit cycle. **This** empirical approach uses a dynamic version of the well known steepest descent adaptation algorithm to adapt the parameters or weights of the RNN so that, after a training period, the network replicates a predetermined periodic signal. **See also Doya and Yoshizawa (1989) for similar results.** This approach does not analyse the mechanism by which the periodic signal is generated nor does it make any attempt to characterise the set of parameter values for which the RNN has periodic solutions. **Consequently**, there is no guarantee that such a set of parameters exists ....

....(approximately) as its output, the periodic teaching signal. **As mentioned in the Introduction, it has been shown experimentally that a class of recurrent networks with configurations similar to the one considered here, are indeed able to learn and replicate certain types of periodic signals, see Doya et al. 1989), Pearlmutter (1995) and Yang et al. 1994) We are interested in proving that such learning and replication has taken place.** In the context of our learning replication process, there are two crucial aspects. **We** must prove that the Teaching Network produces periodic signals as its output and we ....

Doya K., S. Yoshizawa, (1989), '*Adaptive neural oscillator using continuous time backpropagation learning*', Neural Networks, Vol. 2, pp. 375-385.

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Some Observations on the Use of the Extended Kalman Filter as a.. - Williams (1992) (2 citations) (Correct)

....it is McBride and Narendra (1965) More recently, a number of investigators have focused specifically on its use in recurrent neural networks. **These investigators include Robinson and Fallside (1987) Kuhn (1987) Bachrach (1988) Mozer (1989) Williams and Zipser (1989a, 1989b) Gherrity (1989) Doya and Yoshizawa (1989), and Sato (1990a; 1990b) This algorithm was called the infinite impulse response net al..gorithm by Robinson and Fallside, and Narendra and Parthesarathy (1990) have called it dynamic backpropagation.** 5.2 RTRL as a Simplified EKF Variant In the EKF, the (nU nW ) dimensional augmented state ....

Doya, K. &Yoshizawa, S. (1989). *Adaptive neural oscillator using continuous-time back-propagation learning*. Neural Networks, 2, 375-385.

---

Learning to Forget: Continual Prediction with LSTM - Felix A. Gers, Jürgen.. (1999) (2 citations) (Correct)

....gain for some tasks is paid for by a loss of ability to deal with arbitrary, unknown causal delays between inputs and targets. **In fact, state decay does not significantly improve experimental performance (see State Decay in Table 2) Of course we might try to teacher force (Jordan, 1986) (Doya and Shuji, 1989) the internal states s c by resetting them once a new training sequence starts.** But this requires an external teacher that knows how to segment the input stream into training subsequences. **We** are precisely interested, however, in those situations where there is no a priori knowledge of this kind. ....

Doya, K. and Shuji, Y. (1989). *Adaptive neural oscillator using continuous-time backpropagation learning.*

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Simple Learning Algorithm for Recurrent Networks to Realize.. - Shibata (Correct)

....Conventional Learning Algorithm Two typical learning algorithms for the recurrent neural network are proposed. **One** is BPTT (Back Propagation Through Time) 1] etc. **for** discrete time, 2] etc. **for** continuous time) and the other is RTRL (Real Time Recurrent Learning) 3] etc. **for discrete time, [4] etc.** for continuous time) In BPTT, it is necessary to make the error propagate to the past. **This** means that the past states of the neural network have to be stored. **If** the propagation is truncated at T time step, that is called truncated BPTT(T) the neural network cannot memorize the signals ....

Doya, K. and Yoshizawa, S., "*Adaptive neural oscillator using continuous-time back-propagation learning*", Neural Networks, Vol. 2, pp.375-385 (1989)

Long Short-Term Memory - Hochreiter, Schmidhuber (1997) (21 citations) (Correct)

....same (redundant) information. **There are at least two solutions to the abuse problem: 1) Sequential network construction (e.g. Fahlman 1991) a memory cell and the corresponding gate units are added to the network whenever the 2 For intra cellular backprop in a quite different context see also Doya and Yoshizawa (1989).** 3 Following Schmidhuber (1989) we say that a recurrent net al..gorithm is local in space if the update complexity per time step and weight does not depend on network size. **We** say that a method is local in time if its storage requirements do not depend on input sequence length. **For** instance, ....

Doya, K. and Yoshizawa, S. (1989). *Adaptive neural oscillator using continuous-time backpropagation learning.* Neural Networks, 2:375--385.

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Dimension Reduction of Biological Neuron Models by.. - Doya, Selverston (1994) (5 citations) **Self-citation (Doya)** (Correct)

.... **used for compression of high dimensional data vectors, or nonlinear principal component analysis (DeMers and Cottrell 1993; Kramer 1991) This architecture is also suitable for applying the teacher forcing technique, which has been used to train a recurrent network as an autonomous oscillator (Doya and Yoshizawa 1989; Williams and Zipser 1989) Figure 1 shows the basic architecture of dynamical bottleneck network that we designed for dimension reduction of dynamical systems.** When we train the network, the trajectory X 3 (t) x 3 1 (t) x 3 n (t) of the original n dimensional system is given ....

.... **layer and the G layer were derived by the standard back propagation algorithm (Rumelhart et al. 1986) The error gradients with respect to the weights and the time constants of the bottleneck layer and Hlayer were derived using a continuous time version of real time recurrent learning algorithm (Doya and Yoshizawa 1989; Williams and Zipser 1989) as shown in the Appendix.** We tried two parameter update schemes. **In** the batch update scheme, the parameters were updated after running the network for period T by w (k 1) 0 w(k) 0 E w = 0 1 T Z T 0 e(t) w dt; 11) where k denotes the number of ....

[Article contains additional citation context not shown here]

Doya, K. and Yoshizawa, S. 1989. *Adaptive neural oscillator using continuous-time backpropagation learning.* Neural Networks 2, 375--386.

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Bifurcations of Recurrent Neural Networks in Gradient Descent.. - Kenji Doya (1993) (7 citations) **Self-citation (Doya)** (Correct)

....networks can model arbitrary dynamical systems [3] Back propagation learning schemes for multi layer feed forward networks have been successfully applied to a wide range of problems. **In contrast, since gradient descent learning algorithms for recurrent networks became popular several years ago [19, 5, 18, 25], not many cases have been reported about their successful application to large scale problems.** One reason for this is the large cost for gradient computation [26] However, another critical issue in training recurrent networks is bifurcation of the network dynamics. **In** general, asymptotic ....

....that similar problems sudden increase of the error, explosion of the error gradient, and never converging learning process are encountered in training large scale recurrent networks on practical tasks. **Actually in many simulations, we found that the error curves have several steep jumps [5].** Such increase in error is often considered as a numerical artifact, for example, that the trajectory in the parameter space is bouncing between steep cliffs of the error surface, which is frequently encountered in feedforward case [22] However, in the case of recurrent networks, the error ....

[Article contains additional citation context not shown here]

K. Doya and S. Yoshizawa. *Adaptive neural oscillator using continuous-time backpropagation learning.* Neural Networks, 2:375--386, 1989.

---

Supervised Learning in Recurrent Networks - Kenji Doya **Self-citation (Doya)** (Correct)

....network, a change in a weight can affect the future behavior of the entire network. **Learning algorithms that take into account this recurrent effect have been obtained for both discrete time models (Rumelhart et al. 1986; Williams and Zipser, 1989) and continuous time models (Pearlmutter, 1989; Doya and Yoshizawa, 1989; Rowat and Selverston, 1991) The basic principle is to run a linearized version of the network dynamics and estimate the effect of a small change in a weight onto the error function.** There are two ways for doing this sensitivity analysis; one is to run the linearized system forward in time and ....

....have been studied. **Here, we focus on the following model (Pineda, 1988; Pearlmutter, 1989) i y i (t) Gammay i (t) f 0 n m X j=1 w ij z j (t) 1 A ; i = 1; n) 9) z j (t) y j (t) j n u j Gamman j n : However, similar derivations apply to other models as well (Doya and Yoshizawa, 1989; Rowat and Selverston, 1991) We define an error integral E = Z T 0 n X i=1 i (t) 1 2 (y i (t) Gamma d i (t) 2 dt (10) and derive a gradient descent algorithm for minimizing E for a desired trajectory (d 1 (t) d n (t) 0 t T ) with a given initial state (y 1 (0) y n (0)** ....

[Article contains additional citation context not shown here]

Doya, K. and Yoshizawa, S. 1989. *Adaptive neural oscillator using continuous-time backpropagation learning.* Neural Networks 2, 375--386.

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Universality of Fully-Connected Recurrent Neural Networks - Doya (1993) (6 citations) **Self-citation (Doya)** (Correct)

....elaborate architectures have been considered for modeling various classes of dynamical systems [7] Note that the state of such networks is updated sequentially from the input layer to the output layer. **Another approach to modeling dynamical systems is the use of fully connected recurrent networks [2, 8, 9, 10].** In these models, each unit has either a discrete or continuous time delay and is updated in parallel. **If** such units are used to implement the nodes in the two layer recurrent network (as in Figure 1 (a) but now all nodes have delays) the performance of the network is not obvious. **In** a ....

.... **in (10) If we take z(t) j W 1 x(t) 14) as a new state variable, we have from (10) d dt z(t) W 1 d dt x(t) 0W 1 x(t) W 1 W 2 S(W 1 x(t) V u(t) and therefore d dt z(t) 0z(t) W 1 W 2 S(z(t) V u(t) 15) This is another form of continuous time models considered in [4, 2].** 4 Discussion Using the universality theorem of two layer networks, we showed that any discrete or continuoustime dynamical system can be modeled by a fully connected discrete or continuous time recurrent network, respectively, provided the network consists of enough units. **However**, it does not ....

K. Doya and S. Yoshizawa. *Adaptive neural oscillator using continuous-time backpropagation learning.* Neural Networks, 2:375--386, 1989.

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A Hodgkin-Huxley Type Neuron Model That Learns Slow.. - Doya, Selverston, Rowat **Self-citation (Doya)** (Correct)

.... **automatic parameter tuning algorithm for H H type neuron models [5] Since a H H type model is a network of sigmoid functions, multipliers, and leaky integrators (Figure 1) we can tune its parameters in a manner similar to the tuning of connection weights in continuous time neural network models [6, 12].** By training a model from many initial parameter points to match the experimental data, we can systematically estimate a region in the parameter space, instead of a single point. **We** first test if the parameters of a spiking neuron model can be identified from the membrane potential trajectories. ....

....potential trajectory. **We first derive the gradient of E with respect to the model parameters ( i ; g j ; v a j ; s a j ; t a j ; In studies of recurrent neural networks, it has been shown that teacher forcing is very important in training autonomous oscillation patterns [4, 6, 12, 13].** In H H type models, teacher forcing drives the activation and inactivation variables by the target membrane potential v (t) instead of v(t) as follows. **x** = k x (v (t) Delta ( Gammax x1 (v (t) x = a j ; b j ) 6) We use (6) in place of (2) during training. **The** effect of a small ....

[Article contains additional citation context not shown here]

K. Doya and S. Yoshizawa. *Adaptive neural oscillator using continuous-time back-propagation learning.* Neural Networks, 2:375--386, 1989.

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Bifurcations In The Learning Of Recurrent Neural Networks - Kenji Doya (1992) (8 citations) **Self-citation (Doya)** (Correct)

....0; i 6= k: Then the gradient of the average error is derived as follows. **E w kl = 1 T Z T 0 o X i=1 E(t) x i (t) x i (t) w kl dt = 1 T Z T 0 o X i=1 (y i (t) 0 d(t) g 0 (x i (t) p kl i (t)dt: 5) This computation method is called real time recurrent learning (RTRL) [3, 17].** Another method uses the adjoint equation of (4) dq i (t) dt = 1 i q i (t) 0 n X j=1 w ji j g 0 (x i (t) q j (t) 0 ffi i (t) 6) q i (T ) 0; i = 1; n) by using the output error as the input ffi i (t) E(t) x i (t) ae (y i (t) 0 d(t) g 0 (x i (t) i o; ....

....train the network beyond the bifurcation boundaries. 4.1 Non recurrent learning algorithms One simple way to avoid the instability of the learning dynamics is to use a non recurrent learning rules. **Feedforward approximations of recurrent dynamics were successfully used in sequence generation [3, 9] and sequence prediction tasks [2, 5] Those learning rules are derived from (4) by setting the weights w ij to zero except for those of the hidden to output connections (i = 1; o; j = o 1; n) They need only O(on 2 ) computations, whereas RTRL requires O(n 4 )** ....

[Article contains additional citation context not shown here]

Doya, K. and Yoshizawa, S. 1989. *Adaptive neural oscillator using continuous-time back-propagation learning.* Neural Networks, 2, 375--385.

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Adaptive Synchronization of Neural and Physical Oscillators - Doya, Yoshizawa (1992) (2 citations) **Self-citation (Doya Yoshizawa)** (Correct)

....negative and positive feedback pathways are found in those systems. **Elucidation** of the function of the sensory inputs to CPGs requires computational studies of neural and physical dynamical systems. **Algorithms for the learning of rhythmic patterns in recurrent neural networks have been derived by Doya and Yoshizawa (1989), Pearlmutter (1989) and Williams and Zipser (1989) In this paper we propose a learning algorithm for synchronizing a neural oscillator to rhythmic input signals with a specific phase relationship.** It is well known that a coupling between **nonlinear oscillators** can entrainment their frequencies. ....

....curves represent y 1 i (t) and y 2 i (t) respectively. **a**:without coupling. **b**:1T = 0:0. **c**:1T = 1:0. **c**:1T = 2:0. **d**:1T = 3:0. **First, two CPGs were trained independently to oscillate with sinusoidal waveforms of period T 1 = 4:0 and T 2 = 5:0 using continuous time back propagation learning (Doya and Yoshizawa, 1989).** Each CPG was composed of two neurons (C = 2) with time constants = 1:0 and output functions g( tanh( Instead of following the two step procedure described in the previous section, the network dynamics (5) and the learning equations (3) and (6) were simulated concurrently with ....

[Article contains additional citation context not shown here]

Doya, K. & Yoshizawa, S. (1989) *Adaptive neural oscillator using continuous-time back-propagation learning.* Neural Networks, 2, 375--386.

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Nanotechnology

Requests for Comments (RFCs) Database
(Requests for Comments (RFC) document series is a set of technical and organizational notes about the Internet (originally the ARPANET), beginning in 1969 and discussing many aspects of computer networking, including protocols, procedures and concepts as well as meeting notes and opinions.)

➡ Usenet Archive (Google Groups)

➡ Wayback Machine
*(Archived web pages.)*

Submit comments and suggestions to Anne Hendrickson

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Last Modified: 11/19/2003 15:07:41